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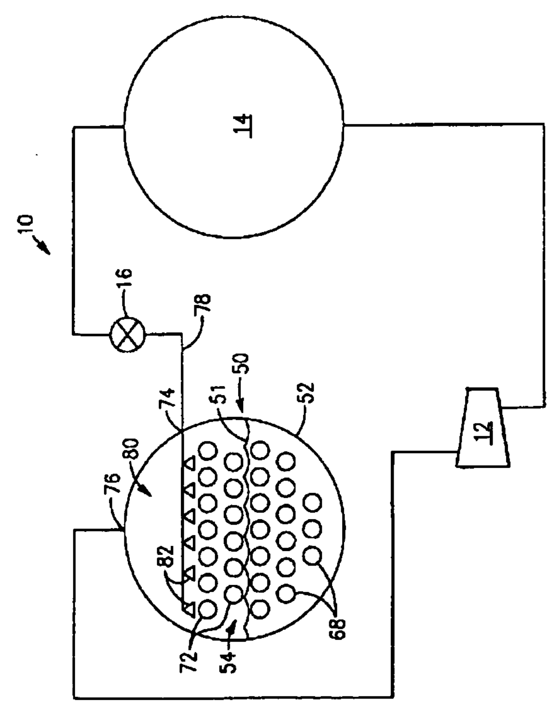
(54)【発明の名称】　蒸気圧縮冷却システム

(57)【要約】

【課題】　一部が流下液膜方式で動作し、一部が満液方式で動作する蒸発器を有するチラーシステムを提供する。

【解決手段】　液体を冷却するための蒸気圧縮冷却システムであって、シェルおよびチューブタイプの蒸発器内のチューブ全体に液状冷媒を分配するためのスプレー分配器が備えられている。蒸発器を通過する冷媒フローのループ内の差圧がスプレー分配器を通る流れを作り出す単一の手段である。蒸発器はハイブリッド流下液膜式熱交換器として、すなわち半満液状態で動作する。チューブバンドルの下の方のチューブを濡らすために、蒸発器シェルの下方部分には液状冷媒が満たされる。上の方のチューブはスプレー分配器からの冷媒スプレーによってのみ濡らされる。



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【特許請求の範囲】

【請求項１】 コンプレッサと、コンデンサと、膨張器と、蒸発器と、をそれぞれ有し、液体を冷却するための蒸気圧縮冷却システムであって、これらコンプレッサとコンデンサと膨張器と蒸発器とは直列に相互連結して冷媒が循環するための冷媒フローの閉ループを形成しており、前記蒸発器は、

上端と下端とを有し、かつ、冷媒入口と冷媒出口とを備える外部シェルを有し、

前記外部シェル内に収容された複数の実質的に水平な伝熱チューブを有し、前記チューブの少なくとも一部は前記シェルの上端と隣接し、前記チューブの少なくとも一部は前記シェルの下端と隣接し、前記チューブは、冷却される液体がそのチューブ内を流れるように形成されており、

前記蒸発器は、前記冷媒入口を介して前記外部シェルに流入する冷媒を受けて前記外部シェルの前記上端に隣接して設けられた前記伝熱チューブ上に冷媒を分配する手段を更に有し、

前記冷媒フローの閉ループは、前記冷却システムの安定動作時に前記外部シェル内の液状冷媒の液位が前記水平チューブの少なくとも２５％が液状冷媒に浸る液位に保持されるよう設計されることを特徴とするシステム。

【請求項２】 前記冷媒フローの閉ループはさらに、前記分配する手段を流れる冷媒の流量が前記冷媒入口から前記冷媒出口へ流れる冷媒の全流量より大きくならないように設計されることを特徴とする請求項１のシステム。

【請求項３】 液状冷媒に浸されていない前記水平チューブは、前記冷却システムの安定動作時に流下液膜伝熱方式で作動することを特徴とする請求項１のシステム。

【請求項４】 前記冷却システムの安定動作時には、好ましくは前記水平チューブの約５０％が液状冷媒に浸されていることを特徴とする請求項１のシステム。

【請求項５】 前記シェルの上端に隣接する伝熱チューブの前記部分は、コンデンサタイプの伝熱チューブであり、前記シェルの下端に隣接する伝熱チューブの前記部分はくぼみ形空胴タイプの伝熱チューブであることを特徴とする請求項３のシステム。

【請求項６】 前記シェルの上端に隣接する伝熱チューブの前記部分および前記シェルの下端に隣接する伝熱チューブの前記部分は同じタイプのチューブであることを特徴とする請求項３のシステム。

【請求項７】 前記蒸発器は、前記冷却されるべき液体が前記外部シェルを介して第１の通路と第２の通路の２つの通路を形成し、前記シェルの前記下端に隣接する前記水平伝熱チューブの第１のグループを通る第１の通路では、前記液体が入口の温度から中間の温度へ温度が低下し、チューブの前記第１のグループの上に配される前記水平伝熱チューブの第２のグループを通る第２の通路では、前記液体は前記中間温度から低い出口温度へ温度が低下することを特徴とする請求項１のシステム。

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【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、流体を冷却するためのシステムに関する。特に、本発明は、システムの蒸発器が満液方式で作動するセクションと流下液膜式方式で作動するセクションとを有する水などの液体を冷却するための蒸気圧縮冷却システムに関する。

【０００２】

【従来の技術】「チラー（冷却装置）」と通常言われる水を冷却するための蒸気圧縮冷却システムは、空調の用途に広く用いられる。このようなシステムは、通常３５０キロワット（１００トン）以上の大きな冷却容量を有し、オフィスビル、大型ストアおよび船などの大型の構造物を冷房するために用いられる。チラーを採用する一般的な用途において、システムには、チラーの蒸発器から冷却されるべき空間に配された数多くの空気／水熱交換器へ水を循環させる冷却水フロー閉ループが含まれる。

【０００３】チラーの別の用途として、産業上の用途における液体のプロセス冷却装置が挙げられる。図１は、従来の典型的なチラー１０の一般的配列を示す。チラー１０において、冷媒はコンプレッサ１２からコンデンサ１４と膨張器１６と蒸発器１８とそしてそこからコンプレッサ１２に戻る閉ループを流れる。コンデンサ１４において、冷媒は、冷媒と熱交換関係にて流入する液体に対して熱を移動させることで冷却される。この流体は、一般的に供給源２０から供給された水である冷却流体である。蒸発器１８において、概略的に符号２２で示されたループからの水は冷媒に対して熱交換関係にて流入し、冷媒に熱を移動させることにより冷却される。

【０００４】チラーの蒸発器は、一般的にシェルおよびチューブタイプの熱交換器、即ち管形熱交換器である。管形熱交換器は、一般的にチューブバンドルと呼ばれる複数のチューブが納められた外部シェルを備える。水などの冷却されるべき液体はチューブバンドルを流れる。沸騰に要するエネルギーは、チューブ間を流れる水から熱として得られる。熱が奪われると、冷却水は空調のためまたは液体冷却プロセスに用いられる。従って、蒸発器シェル内で行われる熱交換を最適化することがチラーの設計の主目的となる。

【０００５】一般的に、面と液状の物質との熱交換率は面とガス状の同一物質との熱交換率よりも高い。このため、効果的かつ有効な熱伝達を実行するには、チラーが作動している間、液状冷媒で覆われたまたはぬらされた状態にチラー蒸発器内のチューブを保持することが重要である。従来のチラー蒸発器のほとんどは、蒸発器の作動中、「満液モード」として知られている方法によってチューブをぬれた状態に保持する目的を達成する。

【0006】この満液モードでは、すべてのチューブが液状冷媒の液位より下になるように蒸発器シェル内の液状冷媒の液位を十分に高くしている。図2は、冷媒液位28よりチューブすべてが下に位置する満液状態で作動しているチラー24を概略的に示す。満液状態におけるチラーの作動により確実にすべてのチューブがぬらされるが、これは特に大容量のチラーでは比較的多量の冷媒を必要とする。冷媒のコストが低い場合には、あまり重要ではないが、コストが増加するにつれ必要とされる冷媒の量が大きなコスト要因となる。これはチラーに必要な冷媒を充填する際における初期費用のみならず、チラーの寿命にわたって維持費および取換えの費用にも影響を与える。

【0007】最近、塩化冷媒（chlorinated refrigerant）に代わるものとして、新たな冷媒がこのようなチラーにおける利用のために導入されている。塩化冷媒は、大気のオゾン層を極端に減少させることが分かりもはや使用されていない。そのような新たな冷媒は、代替される以前のものよりかなり高価である。結果として、チラーのシステムを充填するに必要な冷媒の量を減らすことは、大きな費用削減のみならず、より環境に優しい製品を製造するというニーズを満たす助けとなる。

【0008】冷媒にかかる費用を削減するひとつの方法として、「流下液膜式」蒸発器として知られるものを使用することが挙げられる。流下液膜式蒸発器のコンセプトは、冷媒とチューブの外面との熱伝達が主として対流と伝導とによるものであるということと、適切な熱伝達は液状冷媒のプールにチューブを浸すことによってだけでなく、液膜をチューブの外部表面に連続して補給することによって得られるということを前提としている。したがって、液状冷媒に浸すことによってチューブをぬらすよりも、液状冷媒の流れをチューブに分配する手段を採用することで、チラーに必要とされる冷媒の使用量を減少させコストを低減できる。

【0009】冷媒のフロー即ち流れによって、液状冷媒の膜でチューブの表面をぬれた状態に保ち、これにより全部のチューブバンドルを液状冷媒に浸す必要なくして蒸発器の有効な熱伝達が確保される。このような流れは、蒸発器のチューブバンドルにおける上方のチューブに液状冷媒をスプレーすることにより達成される。そして冷媒は、上方のチューブを覆い、重力の流れによって下方のチューブに流下する。このため、このような熱交換器を「流下液膜式」蒸発器と呼んでる。流下液膜式蒸発器において非常に重要なことは、上の方で冷媒のすべてが蒸発して下の方にぬれていないチューブを残すことがないようにチューブバンドルにわたる液状冷媒の十分な流れがあり、これにより熱伝達に悪影響をおよぼすことがないことである。

【0010】液体が表面をぬらす際に悪影響を及ぼすひとつの要因として、液体の表面張力が挙げられる。一般的に、表面張力が低ければ低いほど、液体が、表面をぬらす傾向が強くなる。たとえば、水は比較的高い表面張力を有し、よって湿潤剤としては比較的劣っている。広く使われている冷媒には、非常に低い表面張力、すなわち華氏２６．６度において１センチにつき３０ダイン以下の表面張力を有し、よって優れた湿潤力を有するものがある。そのような冷媒としては、Ｒ－１３４Ａ、Ｒ－４１０Ａ、Ｒ－４０７Ｃ、Ｒ－４０４およびＲ－１２３などが挙げられる。

【００１１】流下液膜式蒸発器では、比較的高い表面張力を有する冷媒を用いた場合は、特にチューブに分配される冷媒の量が蒸発器を流れる冷媒の総流量と等しい場合、受けいれ可能なコストでは十分な熱伝達が得られないことが分かった。蒸発器を流れる総流量に対する分配冷媒流量を比較するために再循環比が用いられる。これらの流量が等しい場合には、循環比は1に等しいと言える。流下液膜式蒸発器におけるチューブ全体に対して十分な液状冷媒フローを生じさせるために、従来から周知の方法として、蒸発器シェル内で冷媒を再循環するための機械的ポンプを設ける手法が知られている。

【００１２】図3は、チラーシステム３２における流下液膜式の蒸発器３０を概略的に図示する。図２に示された満液式蒸発器と比較すると、膨張器１６から流れる冷媒は、蒸発器シェル３６へ供給ライン３５を経由して入り、チューブ４０の最上部の上に配される、通常スプレーデッキ３８として知られた分配器へ流れる。再循環ポンプ４２を有する再循環回路はライン４４を経由して蒸発器シェルの底部から液体冷媒を引き出し、ライン４６を経由して供給ライン３５へ送る。供給ラインで冷媒は再度スプレーデッキ３８を介して分配される。このようにして、再循環システムは、スプレーデッキ３８を流れる十分な流れを確保し、確実にチューブをぬれた状態に保つ。

【００１３】

【発明が解決しようとする課題】そのような流下液膜蒸発システムにおいては、蒸発器内の液状冷媒のプールの液位４８がチューブバンドル内の最下チューブの下になった状態ですべてのチューブがぬれた状態に保たれる。バンドルのすべてのチューブが確実にぬれるようにするには、再循環比率（スプレーデッキの流量と蒸発器を流れる総流量との比）がおよそ１０対1となるようにする。チューブが浸水されることなく蒸発器が有効に作動可能であるので、そのようなシステムを充填するに必要な冷媒の量は、満液状態で作動する蒸発器を有するシステムと比べると相当に減少される。しかしながら、再循環システムの付加的費用、特にポンプは、冷媒の量を減少させたことによるコスト削減の分を打ち消しかねない。

【００１４】ポンプを必要とすることによる明らかな難点として、費用の増加、低い信頼性、そして高い維持費

が挙げられる。それほど明らかではないが極めて重要なことは、付随的な電力消費量の増加、再循環ポンプを必要とするチラーにおける正味資材利用（net materials utilization）の悪化である。特に、流下液膜式蒸発器において完全なぬれを確保するようポンプが用いられる場合、付随的電力消費量は、チラーの電力消費量における約1％から2％の増加を引き起こし、これは今日の高能率チラーの市場においては著しい増加と考えられ、また地球温暖化の観点から確実な欠点である。

【0015】本発明の目的は、一部が流下液膜方式で動作し、一部が満液方式で動作する蒸発器を有するチラーシステムを提供することである。

【0016】本発明の別の目的は、再循環システムなしで流下液膜式と満液式を結合させた蒸発器を作動させることである。

【0017】本発明のさらに別の目的は、満液式で動作する第1の通路と流下液膜式で動作する第2の通路とを有する二路式蒸発器を作動させることである。

【0018】本発明のさらに別の目的は、第1の通路内の伝熱チューブはくぼみ形空胴タイプの伝熱チューブであり、第2の通路内の伝熱チューブはコンデンサタイプの伝熱チューブであるチラーシステム用二路式蒸発器を提供することである。

【0019】本発明のさらに別の目的は、満液方式で動作する第1の通路と流下液膜式で動作する第2の通路とを有する二路式蒸発器であり、両方の方式においてシングルチューブタイプが最適な熱伝達を行う二路式蒸発器を提供することである。

【0020】

【課題を解決するための手段】これらおよび他の本発明の目的は、コンプレッサとコンデンサと膨張器と蒸発器とを含む液体を冷却するための蒸気圧縮冷却システムにより達成される。コンプレッサとコンデンサと膨張器と蒸発器とは、直列に相互連結して冷媒が循環するための冷媒フローの閉ループを形成している。システムの蒸発器は、上端と、下端と、冷媒入口と、出口と、をそれぞれ有する外部シェルを含む。蒸発器はさらに、外部シェルに収容された複数のほぼ水平な伝熱チューブを含む。伝熱チューブの少なくとも一部はシェルの上端に隣接し、チューブの少なくとも一部はシェルの下端に隣接する。チューブは、冷却される液体がこれらのチューブを流れるように形成されている。

【0021】蒸発器はまた、冷媒入口を経由して外部シェルを通過する冷媒を受け、外部シェルの上端に隣接して配される伝熱チューブに冷媒を分配する手段を含む。冷却システムの冷媒フロー閉ループは、外部シェル内の冷媒の液位が冷却システムの安定した状態の運転時に水平チューブの少なくとも25パーセントが液状冷媒に浸るような液位に保持されるよう構成される。液状冷媒に浸されていない水平チューブは、流下液膜伝達モードにて作動する。そのような安定した運転の際、分配手段を流れる冷媒の流量は、冷媒入口から冷媒出口に流れる冷媒の総流量よりも多くはならない。

【0022】好ましい実施例では、蒸発器は、冷却されるべき液体が外部シェルを経由して2つの通路を形成するタイプのものである。第1の通路はシェルの下端に隣接する水平伝熱チューブの第1のグループを経由し、第2の通路は水平チューブの第2のグループを経由する。

【0023】本発明の他の目的および利点は、添付の図面を用いて次の詳細な説明から明らかにされる。なお添付の図面において同一または相当部材には、同一の符号を付している。

【0024】

【発明の実施の形態】図4は、本発明に係る流下液膜／満液ハイブリッド蒸発器50を組み入れたチラー10を概略的に示す。チラー10は、冷媒がコンプレッサ12からコンデンサ14、膨張装置16、蒸発器50を流れ、その後コンプレッサ12へ戻る標準の冷媒フローの閉ループを採用する。

【0025】蒸発器50は、チューブバンドルにおける複数の水平伝熱チューブ54が貫通する外部シェル52を含む。さらに図5を参照すると、図示された実施例では、蒸発器は、水缶56を一端に有し、入口部60と出口部62とに分割する仕切り58を有する二路式タイプの蒸発器である。入口部60は入口64と、出口部62は出口66とにそれぞれ連通する。入口64を経由して入口部60へ流入した水は、蒸発シェル50の下端に隣接する第1のチューブグループ68を経由して反対側の端部70へ流れる。ここで水は方向を反転し、シェルの上端に隣接する第2のチューブグループ72を経由して水缶56の出口部62へ戻り、ここで出口導管66を経由して水缶から排出される。周知の通り、所望に応じて、より多くの仕切りを用いていくつかの別個でかつ相互に連結されたグループにチューブを分割することで、シェル52を通る水の通路を2つ以上得ることも可能である。

【0026】動作時において、冷媒は、主に液体状態で冷媒入口74を経由して蒸発器50の外部シェル52に流入し、蒸気シェルからは主に気体状態で冷媒出口76を経由して流出する。

【0027】図4および図5の両方に示されるように、入口導管78を介して入口74を経由して蒸発器に流入した冷媒は、チューブ72の第2のグループの最上位置の上に横たわるように配された分配システム80を通る。分配システムは、一連のスプレーヘッドもしくはノズル82からなる。スプレーヘッドもしくはノズルは、蒸発器シェルを通るすべての冷媒がチューブの最上部へ適切に分配または吹き付けられるようにチューブの最上位置の上に配される。

【0028】安定動作状態において、システム10内の

冷媒の充填および冷媒フローの閉ループの全体設計では、外部シェル５２内の液状冷媒の液位５１がシェルの下端近くの水平伝熱チューブの少なくとも２５パーセント（％）が液状冷媒に浸されるような位置に保持されるように設定される。

【００２９】その結果、そのような安定動作状態時には、蒸発器５０は、満液熱伝達方式で作動する蒸発器の下側部分に配されたチューブで動作する一方、液状冷媒に浸されていないチューブは流下液膜式熱伝達方式で作動する。

【００３０】高性能蒸発器では、すべてのチューブから最適な熱伝達が行うためには、すべての伝熱チューブを常に十分にぬらすことが非常に重要である。この結果を達成するには、本発明による流下液膜／満液蒸発器は、冷却システムの安定した動作時に２５パーセントから７５パーセントの水平伝熱チューブが液状冷媒に浸された状態で作動する。好ましい実施例では、システムは、冷却システムの安定した状態において約５０パーセントの伝熱チューブが液状冷媒に浸されるように設計される。

【００３１】ハイブリッド式蒸発器が下から上へ流れるタイプの流路配置に関して示され記述されたが、これは横から横へ流れるタイプの流路配置に適用しても良い。そのような配置では、流入した熱水がチューブバンドルの一方の側を流れ、比較的冷たい水がチューブバンドルのもう一方の側を流れる。

【００３２】本発明のさらに別の好ましい実施例では、蒸発器５０は、冷却されるべき液体が外部シェル５２を経由して２つの通路を形成する上述したようなタイプのものである。この実施例では、第１のまたは下方のチューブグループ６８は、くぼみ形空胴タイプの伝熱チューブとして知られているもので、満液式蒸発器において高性能を発揮するものとして周知である。このようなくぼみ形空胴タイプのチューブの例として、ウォルベリン・チューブ・カンパニー（Wolverine Tube Company）から商業的に入手可能なターボＢ１－３が挙げられる。この実施例において、第２のまたは上方のチューブグループ７２は、コンデンサの用途に用いられるために一般的に設計されたタイプのものであり、特に、ターボＣ１もしくはＣ２の伝熱チューブとしてウォルベリン・チューブ・カンパニーから商業的に入手可能な「スパイクタイプのコンデンサチューブ」タイプのものである。

【００３３】上方および下方側において異なったタイプの伝熱チューブを用いることにより、蒸発器の満液セクションと流下液膜セクションの両方で高い熱伝達係数が達成できる。しかしながら、最終的目標は、流下液膜蒸発器セクションおよび満液蒸発器セクションの両方において熱伝達を最適化することである。チューブは異なったものである必要はない。この目標は、両方の方式で最適な熱伝達を提供できる単一のチューブで実現化される。

【００３４】以上説明した配置の利点は、下から上へ流れるタイプの二路式蒸発器で使用される場合に特に有益である。そのような利点を完全に理解するには、まず典型的二路式蒸発器では、入口６４から流入する水の温度は華氏約５４度であり、この水は第１の通路の終端７０で華氏約４７から４８度に冷却され、出口６６で蒸発器から流出する際にはさらに冷却され華氏約４４度まで冷却されることを理解すべきである。したがって、チューブを通過する水の温度は、下方もしくはプール沸騰セクションにおいて比較的高く、上方もしくは流下液膜熱伝達セクションにおいては比較的低い。

【００３５】このことを念頭において、本実施例の利点は、次のように説明される。プール沸騰係数は、チューブの壁の温度と冷媒の飽和温度との差異として定義される壁過熱（ΔTws）（wall super-heat）の平方にほぼ比例する。逆に、流下液膜蒸発係数は壁過熱の四乗根にほぼ反比例する。このようにして、下から上の流路配置を有する蒸発器の第１の通路では、壁過熱は比較的高く、核沸騰係数が高くなる。しかしながら、満液式蒸発器および同じタイプの伝熱チューブが第２のチューブにあると仮定すると、チューブ側の流体が相対的に冷たくなるに従って壁の過熱が小さくなる第２の通路においては、核沸騰係数は３から４倍も減少するおそれがある。

【００３６】典型的な高能率チラーにおいては、水が熱交換器に入る際の水の温度と冷媒の飽和温度との差は華氏約１２度であり、水が熱交換器からでる際の差は華氏１から２度ほどの小ささである。したがって、第２の通路に入って温度差が小さくなると、流下液膜式の伝熱係数はプール沸騰係数よりも高くなる。これは適切な伝熱表面が本実施例において両方の通路に用いられている場合に特に当てはまる。

【００３７】これにより、本発明による熱交換器は冷媒再循環ポンプなしで作動し、プール沸騰および流下液膜蒸発方式の両方において高い伝熱係数が達成できその利点が得られることが理解できる。

【００３８】以上、本発明を要約すると、本発明は、ハイブリッド流下液膜式蒸発器付きチラーに関し、具体的には、液体を冷却するための蒸気圧縮冷却システムであって、シェルおよびチューブタイプの蒸発器内のチューブ全体に液状冷媒を分配するためのスプレー分配器が備えられている。蒸発器を通過する冷媒フローのループ内の差圧がスプレー分配器を通る流れを作り出す単一の手段である。蒸発器はハイブリッド流下液膜式熱交換器として、すなわち半満液状態で動作する。チューブバンドルの下の方のチューブを濡らすために、蒸発器シェルの下方部分には液状冷媒が満たされる。上の方のチューブはスプレー分配器からの冷媒スプレーによってのみ濡らされる。システムは安定した状態で作動され、よって蒸発器内のチューブの少なくとも２５％が満液熱伝達方式にて作動する。このシステムにより、システム内の冷媒

の充填量を減少することができ、同時に循環システムおよびポンプを使用せずに済む。

【図面の簡単な説明】

【図１】従来のチラーシステムの概略図である。

【図２】満液式蒸発器を有する従来のチラーシステムの部分概略図である。

【図３】流下液膜式蒸発器を有する従来のチラーシステムの部分概略図である。

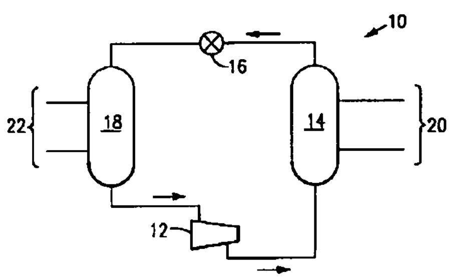
【図４】本発明による流下液膜／満液ハイブリッド蒸発器を有するチラーシステムの概略図である。

【図５】図４に示されたタイプの流下液膜／満液ハイブリッド蒸発器の簡略化した断面図である。

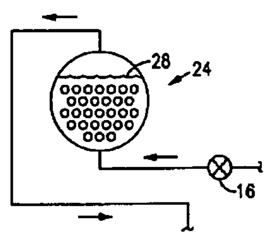
【符号の説明】

１０…チラー
１２…コンプレッサ
１４…コンデンサ
１６…膨張装置
５０…流下液膜／満液ハイブリッド蒸発器
５２…外部シェル
５４…水平伝熱チューブ
５６…水缶
６８…第１のチューブグループ
７４…冷媒入口
７６…冷媒出口
７８…入口導管
８０…分配システム

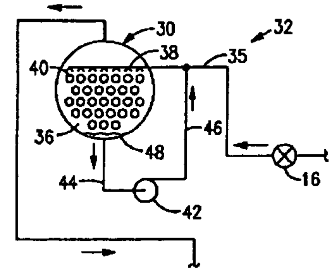
【図１】



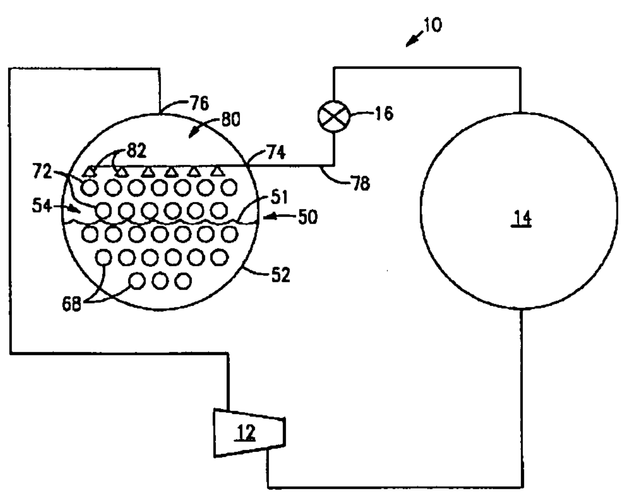
【図２】



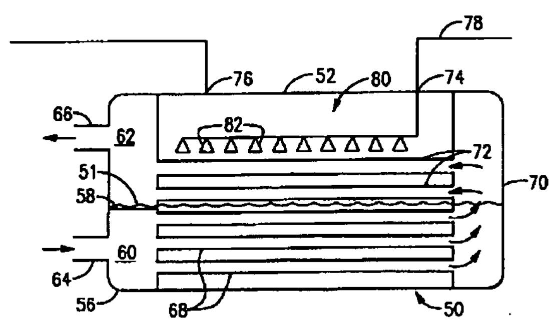
【図３】



【図４】



【図５】



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ABSTRACT:

PROBLEM TO BE SOLVED: To provide an evaporator a portion of which is operated in a falling liquid film heat transfer method and another portion of which is operated in an immersion heat transfer method at the time of a stable operation of a refrigerating system, by a method wherein the liquid level of a refrigerant in an outer shell is held at a level which makes a specified percentage of horizontal tubes immersed in the liquefied refrigerant.

SOLUTION: A refrigerant which flows into an evaporator 50 through an inlet 74 by way of an inlet conduit 78 passes through a distribution system 80 which is made of a plurality of nozzles 82 disposed horizontally above the uppermost positioned tubes of a second group of tubes 72. In a stable operating condition, a closed loop of a refrigerating flow in a system 10 is formed such that the liquid level 51 of a liquefied refrigerant in the outer shell 52 is positioned at a level where at least 25 percent of a plurality of horizontal heat transfer tubes located close to the lower end of the shell is immersed in the refrigerant. Accordingly, the evaporator 50 is operated such that the tubes which are disposed at the lower side portion of the evaporator are operated in an immersion heat transfer method while the tubes which are not immersed in the liquefied refrigerant are operated in a falling liquid film heat transfer method.

* NOTICES *

CLAIMS

[Claim(s)]
[Claim 1] It has a compressor, a capacitor, an expander, and an evaporator, respectively. Are a steamy compression cooling system for cooling a liquid, and the closed loop of a refrigerant flow to link these compressors, a capacitor, an expander, and an evaporator to a serial, and for a refrigerant circulate through them is formed. It has the external shell which said evaporator has upper limit and a lower limit, and is equipped with a refrigerant inlet port and a refrigerant outlet. It has a level heat transfer tube substantially [plurality] which was held in said external shell. Said some of tubes [at least] adjoin the upper limit of said shell, and said some of tubes [at least] adjoin the lower limit of said shell. Said tube It is formed so that the liquid cooled may flow the inside of the tube. Said evaporator It has further a means to distribute a refrigerant on said heat transfer tube adjoined and prepared in said upper limit of said external shell in response to the refrigerant which flows into said external shell through said refrigerant inlet port. The closed loop of said refrigerant flow is a system by which it is characterized by designing said at least 25% of level tube so that the liquid level of the liquefied refrigerant in said external shell may be held at the liquid level to which it floods with a liquefied refrigerant at the time of operational stability of said cooling system.
[Claim 2] The closed loop of said refrigerant flow is the system of claim 1 characterized by being designed so that the flow rate of the refrigerant which flows said means to distribute may not become larger than the full flow of the refrigerant which flows from said refrigerant inlet port to said refrigerant outlet further.
[Claim 3] Said level tube which is not dipped in a liquefied refrigerant is the system of claim 1 characterized by operating by the flowing-down liquid membrane heat transfer method at the time of operational stability of said cooling system.
[Claim 4] It is the system of claim 1 characterized by dipping said about 50% of level tube in the liquefied refrigerant preferably at the time of operational stability of said cooling system.
[Claim 5] Said part of the heat transfer tube which said part of the heat transfer tube which adjoins the upper limit of said shell is a capacitor type heat transfer tube, and adjoins the lower limit of said shell is the system of claim 3 characterized by being a reentrant cavity type heat transfer tube.
[Claim 6] Said part of the heat transfer tube contiguous to said part of the heat transfer tube which adjoins the upper limit of said shell, and the lower limit of said shell is the system of claim 3 characterized by being a tube same type.
[Claim 7] As for said evaporator, said liquid which should be cooled forms two paths, the 1st path and the 2nd path, through said external shell. At the 1st path which passes along the 1st group of said level heat transfer tube contiguous to said lower limit of said shell For said liquid, said liquid is the system of claim 1 to which it is characterized by temperature falling to low outlet temperature from said intermediate temperature in the 2nd path which passes along the 2nd group of said level heat transfer tube who temperature falls from the temperature of an inlet port to middle temperature, and is allotted on said 1st group of a tube.

[Translation done.]

* NOTICES *

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3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] This invention relates to the system for cooling a fluid. Especially this invention relates to the steamy compression cooling system for cooling liquids, such as water which has the section where the evaporator of a system operates by the filled-liquid method, and the section which operates by the falling-film-evaporator method.
[0002]
[Description of the Prior Art] The steamy compression cooling system for cooling the water usually called "chiller (cooling system)" is widely used for the application of air-conditioning. Such a system usually has a big cooling capacity more than 350kW (100t), and it is used in order to air-condition the large-sized structures, such as an office building, a large-sized store, and a ship. In the general application which adopts a chiller, the cooling water flow closed loop which circulates water to many air / hydrothermal exchangers which were allotted to the space which should be cooled from the evaporator of a chiller is contained in a system.
[0003] As another application of a chiller, the process cooling system of the liquid in the application on industry is mentioned. Drawing 1 shows the general array of the conventional typical chiller 10. a chiller 10 -- setting -- a refrigerant -- a compressor 12 to the capacitor 14, an expander 16, and an evaporator 18 -- and the closed loop which returns from there to a compressor 12 is flowed. In a capacitor 14, a refrigerant is cooled by moving heat to the liquid which flows by the refrigerant and heat exchange relation. This fluid is a cooling fluid which is water generally supplied from the source of supply 20. In an evaporator 18, the water from the loop formation roughly shown with the sign 22 flows by heat exchange relation to a refrigerant, and is cooled by moving heat to a refrigerant.
[0004] Generally the evaporators of a chiller are shell and a tube type heat exchanger, i.e., tubular type heat exchanger. Tubular type heat exchanger is equipped with the external shell to which two or more tubes generally called a bundle were dedicated. Liquids which should be cooled, such as water, flow a bundle. The energy which ebullition takes is obtained from the water which flows between tubes as heat. Cooling water will be used for the liquid cooling process for air-conditioning if heat is taken. Therefore, it becomes the key objective of a design of a chiller to optimize the heat exchange performed within evaporator shell.
[0005] Generally, the effectiveness of a field and the liquefied matter is higher than the effectiveness of a field and the same gas matter. For this reason, in order to perform effective and effective heat transfer, while the chiller is operating, it is important for the condition of it having been covered or having soaked in the liquefied refrigerant to hold the tube in a chiller evaporator. Most conventional chiller evaporators attain the purpose which holds a tube in the condition of having wetted wet, by the approach learned as "filled-liquid mode" during actuation of an evaporator.
[0006] In this filled-liquid mode, liquid level of the liquefied refrigerant in evaporator shell is made high enough so that all tubes may come below the liquid level of a liquefied refrigerant. Drawing 2 shows roughly the chiller 24 with which all tubes are operating in the state of filled-liquid [which is located downward] from the refrigerant liquid level 28. Although all tubes are certainly soaked by actuation of the chiller in a filled-liquid condition, this needs comparatively a lot of refrigerants with a mass chiller especially. Although it is not so important when the cost of a refrigerant is low, the amount of the refrigerant needed as cost increases serves

as a big cost factor. This also affects a sustaining cost and the costs of exchange over the life of not only the front end cost at the time of being filled up with a refrigerant required for a chiller but a chiller.

[0007] Recently, the refrigerant new as a thing which replaces a chlorination refrigerant (chlorinated refrigerant) is introduced for the use in such a chiller. Also understanding is not already used for a chlorination refrigerant decreasing an atmospheric ozone layer extremely. Such a new refrigerant becomes in the thing twist before substituting and is expensive. Reducing the amount of a refrigerant required as a result to be filled up with the system of a chiller helps to fill the needs of manufacturing not only big costs reduction but a more environment-friendly product.

[0008] Using what is known as a "falling-film-evaporator" evaporator as one approach of reducing the costs concerning a refrigerant is mentioned. The concept of a falling-film-evaporator evaporator being what heat transfer of a refrigerant and the external surface of a tube depends mainly on the convection current and conduction, and suitable heat transfer are premised on being obtained by continuing and supplying liquid membrane to the outer surface of a tube only by dipping a tube in the pool of a liquefied refrigerant. Therefore, by dipping in a liquefied refrigerant, by adopting a means to distribute the flow of a liquefied refrigerant to a tube, the amount of the refrigerant used needed for a chiller is decreased, and cost can be reduced rather than soaking a tube.

[0009] The film of a liquefied refrigerant does not need to maintain the front face of a tube at the condition of having wetted wet, it is necessary to dip no bundles in a liquefied refrigerant by this, and effective heat transfer of an evaporator is secured, the flow, i.e., the flow, of a refrigerant. Such flow is attained by carrying out the spray of the liquefied refrigerant to the upper tube in the bundle of an evaporator. And a refrigerant covers an upper tube and flows down in a downward tube by the flow of gravity. For this reason, such a heat exchanger is called the "falling-film-evaporator" evaporator. flow with the liquefied refrigerant sufficient so that that it is very important in a falling-film-evaporator evaporator may not leave the tube which all the refrigerants evaporate in the upper one and is not damp in the lower one covering a bundle -- it is -- thereby -- heat transfer -- a bad influence -- ****** -- it is that there are nothings.

[0010] In case a liquid soaks a front face, the surface tension of a liquid is mentioned as one factor which does a bad influence. Generally, as surface tension is low, the inclination for a liquid to soak a front face becomes stronger. For example, water has comparatively high surface tension and, therefore, is comparatively inferior as a wetting agent. There are some which have the surface tension of 30 dynes or less per cm in 26.6 very low surface tension, i.e., Fahrenheit, and have the wetting power which was therefore excellent in the refrigerant currently used widely. As such a refrigerant, R-134A, R-410A, R-407C, R-404, R-123, etc. are mentioned.

[0011] In the falling-film-evaporator evaporator, when the amount of the refrigerant distributed to a tube especially when the refrigerant which has comparatively high surface tension is used was equal to the total flow of the refrigerant which flows an evaporator, it turned out that heat transfer sufficient at acceptable cost is not obtained. A recycle ratio is used in order to measure the distribution refrigerant flow rate to the total flow which flows an evaporator. When these flow rates are equal, it can be said that a recycle ratio is equal to 1. Since sufficient liquefied refrigerant flow is produced to the whole tube in a falling-film-evaporator evaporator, the technique of forming the mechanical pump for recycling a refrigerant within evaporator shell is known as the well-known approach from the former.

[0012] Drawing 3 illustrates roughly the evaporator 30 of the falling film evaporator in the chiller system 32. The refrigerant which flows from an expander 16 as compared with the filled liquid system evaporator shown in drawing 2 goes into the evaporator shell 36 via a supply line 35, and flows to the distributor which is arranged on the topmost part of a tube 40 and which was usually known as the spray deck 38. The recycling circuit which has a recirculation pump 42 pulls out a liquid cryogen from the pars basilaris ossis occipitalis of evaporator shell via Rhine 44, and sends it to a supply line 35 via Rhine 46. A refrigerant is again distributed through the spray deck 38 by the supply line. Thus, a recycling system secures sufficient flow which flows the spray deck 38, and keeps a tube certain in the condition of having wetted wet.

[0013]

[Problem(s) to be Solved by the Invention] It is maintained at the condition that all the tubes were damp after the liquid level 48 of the pool of the liquefied refrigerant in an evaporator had become the bottom of the lowest tube in a bundle, in such a flowing-down liquid membrane evaporation system. In order to make it certainly

damp [all the tubes of a bundle], it is made for the rate of a recycle ratio (ratio of the flow rate of the spray deck and the total flow which flows an evaporator) to be set to about 10 to 1. Since an evaporator can operate effectively, without flooding a tube, the amount of a refrigerant required to be filled up with such a system decreases fairly compared with the system which has the evaporator which operates in the state of filled-liquid. However, the additional costs of a recycling system, especially a pump may negate the part of the cost reduction by having decreased the amount of a refrigerant.

[0014] As a clear difficulty by needing a pump, the increment in costs, low dependability, and a high sustaining cost are mentioned. Things very important although it is not so clear are the increment in subordinate power consumption, and aggravation of the net materials use (net materials utilization) in the chiller which needs a recirculation pump. When a pump is used so that perfect wetting may be especially secured in a falling-film-evaporator evaporator, subordinate power consumption causes about 1 to 2% of increment, and this is considered to be a remarkable increment in the commercial scene of today's high efficiency chiller, and it is a positive fault from a viewpoint of global warming. [in the power consumption of a chiller]

[0015] The purpose of this invention is offering the chiller system which has the evaporator to which a part's operates by the flowing-down liquid membrane method, and a part's operates by the filled-liquid method.

[0016] Another purpose of this invention is operating the evaporator which combined the falling film evaporator and the filled liquid system without the recycling system.

[0017] Still more nearly another purpose of this invention is operating the 2 way type evaporator which has the 1st path which operates by the filled liquid system, and the 2nd path which operates by the falling film evaporator.

[0018] The heat transfer tube in the 1st path of still more nearly another purpose of this invention is a reentrant cavity type heat transfer tube, and the heat transfer tube in the 2nd path is offering the 2 way type evaporator for chiller systems which is a capacitor type heat transfer tube.

[0019] Still more nearly another purpose of this invention is [in / are the 2 way type evaporator which has the 1st path which operates by the filled-liquid method, and the 2nd path which operates by the falling film evaporator, and / both methods] offering the 2 way type evaporator which performs heat transfer with the optimal single tube type.

[0020]

[Means for Solving the Problem] The purpose of these and other this inventions is attained by the steamy compression cooling system for cooling the liquid containing a compressor, a capacitor, an expander, and an evaporator. The compressor, the capacitor, the expander, and the evaporator form the closed loop of a refrigerant flow to link to a serial and for a refrigerant circulate. The evaporator of a system contains the external shell which has upper limit, a lower limit, a refrigerant inlet port, and an outlet, respectively. An evaporator contains further two or more almost level heat transfer tubes held in external shell. Some heat transfer tubes [at least] adjoin the upper limit of shell, and some tubes [at least] adjoin the lower limit of shell. shell. The tube is formed so that the liquid cooled may flow these tubes.

[0021] An evaporator receives the refrigerant which passes external shell via a refrigerant inlet port again, and includes a means to distribute a refrigerant to the heat transfer tube adjoined and arranged on the upper limit of external shell. The refrigerant flow closed loop of a cooling system is constituted so that it may be held at liquid level to which at least 25% of a level tube is flooded with a liquefied refrigerant at the time of operation in the condition that the cooling system was stabilized by the liquid level of the refrigerant in external shell. The level tube which is not dipped in a liquefied refrigerant operates in flowing-down liquid membrane transfer mode. Many do not consist of the total flow of the refrigerant with which the flow rate of the refrigerant which flows a distribution means flows from a refrigerant inlet port to a refrigerant outlet in the case of such stable operation.

[0022] In the desirable example, an evaporator is the thing of the type with which the liquid which should be cooled forms two paths via external shell. The 2nd path goes via the 2nd group of a level tube via the 1st group of the level heat transfer tube with which the 1st path adjoins the lower limit of shell.

[0023] Other purposes and advantages of this invention are made clear from the following detailed explanation using an attached drawing. In addition, in the attached drawing, the sign identically same to a considerable member is attached.

[0024]

[Embodiment of the Invention] Drawing 4 shows roughly the chiller 10 which incorporated the flowing-down liquid membrane / filled-liquid hybrid evaporator 50 concerning this invention. The closed loop of the refrigerant flow of the criterion which a refrigerant flows a capacitor 14, expansion equipment 16, and an evaporator 50 from a compressor 12, and returns to a compressor 12 after that is used for a chiller 10.
[0025] An evaporator 50 contains the external shell 52 which two or more level heat transfer tubes 54 which can be set to a bundle penetrate. When drawing 5 is furthermore referred to, in the illustrated example, an evaporator is an evaporator of the 2 way type type which has a water can 56 at the end and has the partition 58 divided into the inlet-port section 60 and the outlet section 62. The inlet-port section 60 opens an inlet port 64 and the outlet section 62 for free passage to an outlet 66, respectively. The water which flowed into the inlet-port section 60 via the inlet port 64 flows to the edge 70 of the opposite side via the 1st tube group 68 which adjoins the lower limit of the evaporation shell 50. the 2nd tube group 72 which water reverses a direction here and adjoins the upper limit of shell -- going -- the outlet section 62 of a water can 56 -- return and here -- an outlet -- it is discharged from a water can via a conduit 66. According to the request, more partitions are used as everyone knows, and shoes are separate, and it is also possible to obtain two or more paths of the water which passes along shell 52 by dividing a tube into the group connected mutually.
[0026] At the time of actuation, a refrigerant mainly flows into the external shell 52 of an evaporator 50 via the refrigerant inlet port 74 in the state of a liquid, and mainly flows out of steamy shell via the refrigerant outlet 76 by the gaseous state.
[0027] it is shown in both drawing 4 and drawing 5 -- as -- an inlet port -- the refrigerant which flowed into the evaporator via the inlet port 74 through the conduit 78 passes along the distribution system 80 arranged so that it might lie on the best location of the 2nd group of a tube 72. A distribution system consists of a series of spray heads or nozzles 82. all the refrigerants with which a spray head or a nozzle passes along evaporator shell -- the topmost part of a tube -- suitable -- distribution -- or it is allotted on the best location of a tube so that it may be sprayed.
[0028] In an operational stability condition, by restoration of the refrigerant in a system 10, and the design by the whole closed loop of a refrigerant flow, the liquid level 51 of the liquefied refrigerant in the external shell 52 is set up so that at least 25% of the level heat transfer tube near the lower limit of shell (%) may be held in a location which is dipped in a liquefied refrigerant.
[0029] Consequently, in such an operational stability condition, while an evaporator 50 operates by the tube arranged on the lower part of the evaporator which operates by the filled-liquid heat transfer method, the tube which is not dipped in a liquefied refrigerant operates by the falling-film-evaporator heat transfer method.
[0030] It is very important to always fully soak all heat transfer tubes in a high performance evaporator, in order for the optimal heat transfer to carry out from all tubes. In order to attain this result, the flowing-down liquid membrane / filled-liquid evaporator by this invention operate, where 25 to 75% of level heat transfer tube is dipped in a liquefied refrigerant at the time of the actuation by which the cooling system was stabilized. In the desirable example, a system is designed so that about 50% of heat transfer tube may be dipped in a liquefied refrigerant in the condition that the cooling system was stabilized.
[0031] Although the hybrid type evaporator was shown and described about passage arrangement of the type which flows upwards from the bottom, this may be applied to passage arrangement of the type which flows from width to width. In such arrangement, the hot water which flowed flows one bundle side, and comparatively cold water flows another bundle side.
[0032] In the still more nearly another desirable example of this invention, an evaporator 50 is the thing of a type with which the liquid which should be cooled forms two paths via the external shell 52 and which was mentioned above. In this example, the tube group 68 of the 1st or a lower part is common knowledge as what is known as a reentrant cavity type heat transfer tube, and demonstrates high performance in a filled liquid system evaporator. As an example of a such reentrant cavity type tube, available turbo B1-3 are commercially mentioned from a WORUBERIN tube company (Wolverine Tube Company). In this example, since the 2nd or the upper tube group 72 is used for the application of a capacitor, he is the thing of the type generally designed, and he is a thing available "spike type capacitor tube" type especially commercially from WORUBERIN Tube Company as a turbo C1 or a heat transfer tube of C2.
[0033] By using the heat transfer tube of a type which is different in an upper part and lower part side, a high

heat transfer coefficient can be attained with both the filled-liquid section of an evaporator, and a flowing-down liquid membrane section. However, a final target is optimizing heat transfer in both a flowing-down liquid membrane evaporator section and a filled-liquid evaporator section. Tubes do not need to differ. This target is implementation-ized by the single tube which can offer the optimal heat transfer by both methods.

[0034] The advantage of the arrangement explained above is useful especially when used with the 2 way type evaporator of the type which flows upwards from the bottom. In order to understand such an advantage completely, first, with the typical 2 way type evaporator, the temperature of the water which flows from an inlet port 64 is about 54 Fahrenheit, and he should understand that are cooled by 48 degrees from Fahrenheit 47 [about] at the termination 70 of the 1st path, and it is cooled further and it is cooled to about 44 Fahrenheit in case this water flows out of an evaporator at an outlet 66. Therefore, the temperature of the water which passes a tube is comparatively high in a lower part or a pool boiling section, and comparatively low in the upper part or a flowing-down liquid membrane heat transfer section.

[0035] The advantage of this example is explained as follows bearing this in mind. A pool boiling multiplier is proportional to square [of wall overheating (deltaTWS) (wall super-heat) defined as a difference between the temperature of the wall of a tube, and the saturation temperature of a refrigerant] mostly. On the contrary, flowing-down liquid membrane factor of evaporation is mostly in inverse proportion to the 4 roots of wall overheating. Thus, at the 1st path of the evaporator which has the upper passage arrangement from the bottom, wall overheating is comparatively high and a nucleate-boiling multiplier becomes high. However, when it assumes that a filled liquid system evaporator and a heat transfer tube same type are in the 2nd tube, at the 2nd path where overheating of a wall becomes small as the fluid of a tubeside gets cold relatively, a nucleate-boiling multiplier has a possibility of decreasing also 3 to 4 times.

[0036] In a typical high efficiency chiller, the differences of the temperature of the water at the time of water going into a heat exchanger and the saturation temperature of a refrigerant are about 12 Fahrenheit, and the difference at the time of water coming out of a heat exchanger is the smallness of about 2 times from Fahrenheit 1. Therefore, if it goes into the 2nd path and a temperature gradient becomes small, the heat transfer coefficient of a falling film evaporator will become higher than a pool boiling multiplier. This is applied especially when the suitable heat transfer front face is used for both paths in this example.

[0037] He can understand that the heat exchanger by this invention operates without a refrigerant recirculation pump, can attain a high heat transfer coefficient in both pool boiling and a flowing-down liquid membrane evaporation method, and the advantage is acquired by this.

[0038] As mentioned above, if this invention is summarized, this invention is a steamy compression cooling system for specifically cooling a liquid about a chiller with a hybrid falling-film-evaporator evaporator, and it has the spray distributor for distributing a liquefied refrigerant to the whole tube in shell and a tube type evaporator. The differential pressure within the loop formation of the refrigerant flow which passes an evaporator is the single means which makes the flow which passes along a spray distributor. An evaporator operates as a hybrid falling-film-evaporator heat exchanger (i.e., a condition [half-filled-liquid]). A liquefied refrigerant is filled by the lower part part of evaporator shell in order to wet the tube in the direction of under a bundle. The tube of the upper one is wet only by the refrigerant spray from a spray distributor. A system operates in the condition of having been stabilized and, therefore, at least 25% of the tube in an evaporator operates by the filled-liquid heat transfer method. The fill of the refrigerant in a system can be decreased and it is not necessary to use a circulation system and a pump for coincidence by this system.

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TECHNICAL FIELD

[Field of the Invention] This invention relates to the system for cooling a fluid. Especially this invention relates to the steamy compression cooling system for cooling liquids, such as water which has the section where the evaporator of a system operates by the filled-liquid method, and the section which operates by the falling-film-evaporator method.

[Translation done.]

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PRIOR ART

[Description of the Prior Art] The steamy compression cooling system for cooling the water usually called "chiller (cooling system)" is widely used for the application of air-conditioning. Such a system usually has a big cooling capacity more than 350kW (100t), and it is used in order to air-condition the large-sized structures, such as an office building, a large-sized store, and a ship. In the general application which adopts a chiller, the cooling water flow closed loop which circulates water to many air / hydrothermal exchangers which were allotted to the space which should be cooled from the evaporator of a chiller is contained in a system.
[0003] As another application of a chiller, the process cooling system of the liquid in the application on industry is mentioned. Drawing 1 shows the general array of the conventional typical chiller 10. a chiller 10 -- setting -- a refrigerant -- a compressor 12 to the capacitor 14, an expander 16, and an evaporator 18 -- and the closed loop which returns from there to a compressor 12 is flowed. In a capacitor 14, a refrigerant is cooled by moving heat to the liquid which flows by the refrigerant and heat exchange relation. This fluid is a cooling fluid which is water generally supplied from the source of supply 20. In an evaporator 18, the water from the loop formation roughly shown with the sign 22 flows by heat exchange relation to a refrigerant, and is cooled by moving heat to a refrigerant.
[0004] Generally the evaporators of a chiller are shell and a tube type heat exchanger, i.e., tubular type heat exchanger. Tubular type heat exchanger is equipped with the external shell to which two or more tubes generally called a bundle were dedicated. Liquids which should be cooled, such as water, flow a bundle. The energy which ebullition takes is obtained from the water which flows between tubes as heat. Cooling water will be used for the liquid cooling process for air-conditioning if heat is taken. Therefore, it becomes the key objective of a design of a chiller to optimize the heat exchange performed within evaporator shell.
[0005] Generally, the effectiveness of a field and the liquefied matter is higher than the effectiveness of a field and the same gas matter. For this reason, in order to perform effective and effective heat transfer, while the chiller is operating, it is important for the condition of it having been covered or having soaked in the liquefied refrigerant to hold the tube in a chiller evaporator. Most conventional chiller evaporators attain the purpose which holds a tube in the condition of having wetted wet, by the approach learned as "filled-liquid mode" during actuation of an evaporator.
[0006] In this filled-liquid mode, liquid level of the liquefied refrigerant in evaporator shell is made high enough so that all tubes may come below the liquid level of a liquefied refrigerant. Drawing 2 shows roughly the chiller 24 with which all tubes are operating in the state of filled-liquid [which is located downward] from the refrigerant liquid level 28. Although all tubes are certainly soaked by actuation of the chiller in a filled-liquid condition, this needs comparatively a lot of refrigerants with a mass chiller especially. Although it is not so important when the cost of a refrigerant is low, the amount of the refrigerant needed as cost increases serves as a big cost factor. This also affects a sustaining cost and the costs of exchange over the life of not only the front end cost at the time of being filled up with a refrigerant required for a chiller but a chiller.
[0007] Recently, the refrigerant new as a thing which replaces a chlorination refrigerant (chlorinated refrigerant) is introduced for the use in such a chiller. Also understanding is not already used for a chlorination refrigerant decreasing an atmospheric ozone layer extremely. Such a new refrigerant becomes in the thing twist before substituting and is expensive. Reducing the amount of a refrigerant required as a result to be filled up with the system of a chiller helps to fill the needs of manufacturing not only big costs reduction but a more

environment-friendly product.

[0008] Using what is known as a "falling-film-evaporator" evaporator as one approach of reducing the costs concerning a refrigerant is mentioned. The concept of a falling-film-evaporator evaporator being what heat transfer of a refrigerant and the external surface of a tube depends mainly on the convection current and conduction, and suitable heat transfer are premised on being obtained by continuing and supplying liquid membrane to the outer surface of a tube only by dipping a tube in the pool of a liquefied refrigerant. Therefore, by dipping in a liquefied refrigerant, by adopting a means to distribute the flow of a liquefied refrigerant to a tube, the amount of the refrigerant used needed for a chiller is decreased, and cost can be reduced rather than soaking a tube.

[0009] The film of a liquefied refrigerant does not need to maintain the front face of a tube at the condition of having wetted wet, it is necessary to dip no bundles in a liquefied refrigerant by this, and effective heat transfer of an evaporator is secured, the flow, i.e., the flow, of a refrigerant. Such flow is attained by carrying out the spray of the liquefied refrigerant to the upper tube in the bundle of an evaporator. And a refrigerant covers an upper tube and flows down in a downward tube by the flow of gravity. For this reason, such a heat exchanger is called the "falling-film-evaporator" evaporator. flow with the liquefied refrigerant sufficient so that that it is very important in a falling-film-evaporator evaporator may not leave the tube which all the refrigerants evaporate in the upper one and is not damp in the lower one covering a bundle -- it is -- thereby -- heat transfer -- a bad influence -- ****** -- it is that there are nothings.

[0010] In case a liquid soaks a front face, the surface tension of a liquid is mentioned as one factor which does a bad influence. Generally, as surface tension is low, the inclination for a liquid to soak a front face becomes stronger. For example, water has comparatively high surface tension and, therefore, is comparatively inferior as a wetting agent. There are some which have the surface tension of 30 dynes or less per cm in 26.6 very low surface tension, i.e., Fahrenheit, and have the wetting power which was therefore excellent in the refrigerant currently used widely. As such a refrigerant, R-134A, R-410A, R-407C, R-404, R-123, etc. are mentioned.

[0011] In the falling-film-evaporator evaporator, when the amount of the refrigerant distributed to a tube especially when the refrigerant which has comparatively high surface tension is used was equal to the total flow of the refrigerant which flows an evaporator, it turned out that heat transfer sufficient at acceptable cost is not obtained. A recycle ratio is used in order to measure the distribution refrigerant flow rate to the total flow which flows an evaporator. When these flow rates are equal, it can be said that a recycle ratio is equal to 1. Since sufficient liquefied refrigerant flow is produced to the whole tube in a falling-film-evaporator evaporator, the technique of forming the mechanical pump for recycling a refrigerant within evaporator shell is known as the well-known approach from the former.

[0012] Drawing 3 illustrates roughly the evaporator 30 of the falling film evaporator in the chiller system 32. The refrigerant which flows from an expander 16 as compared with the filled liquid system evaporator shown in drawing 2 goes into the evaporator shell 36 via a supply line 35, and flows to the distributor which is arranged on the topmost part of a tube 40 and which was usually known as the spray deck 38. The recycling circuit which has a recirculation pump 42 pulls out a liquid cryogen from the pars basilaris ossis occipitalis of evaporator shell via Rhine 44, and sends it to a supply line 35 via Rhine 46. A refrigerant is again distributed through the spray deck 38 by the supply line. Thus, a recycling system secures sufficient flow which flows the spray deck 38, and keeps a tube certain in the condition of having wetted wet.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] It is maintained at the condition that all the tubes were damp after the liquid level 48 of the pool of the liquefied refrigerant in an evaporator had become the bottom of the lowest tube in a bundle, in such a flowing-down liquid membrane evaporation system. In order to make it certainly damp [all the tubes of a bundle], it is made for the rate of a recycle ratio (ratio of the flow rate of the spray deck and the total flow which flows an evaporator) to be set to about 10 to 1. Since an evaporator can operate effectively, without flooding a tube, the amount of a refrigerant required to be filled up with such a system decreases fairly compared with the system which has the evaporator which operates in the state of filled-liquid. However, the additional costs of a recycling system, especially a pump may negate the part of the cost reduction by having decreased the amount of a refrigerant.
[0014] As a clear difficulty by needing a pump, the increment in costs, low dependability, and a high sustaining cost are mentioned. Things very important although it is not so clear are the increment in subordinate power consumption, and aggravation of the net materials use (net materials utilization) in the chiller which needs a recirculation pump. When a pump is used so that perfect wetting may be especially secured in a falling-film-evaporator evaporator, subordinate power consumption causes about 1 to 2% of increment, and this is considered to be a remarkable increment in the commercial scene of today's high efficiency chiller, and it is a positive fault from a viewpoint of global warming. [in the power consumption of a chiller]
[0015] The purpose of this invention is offering the chiller system which has the evaporator to which a part's operates by the flowing-down liquid membrane method, and a part's operates by the filled-liquid method.
[0016] Another purpose of this invention is operating the evaporator which combined the falling film evaporator and the filled liquid system without the recycling system.
[0017] Still more nearly another purpose of this invention is operating the 2 way type evaporator which has the 1st path which operates by the filled liquid system, and the 2nd path which operates by the falling film evaporator.
[0018] The heat transfer tube in the 1st path of still more nearly another purpose of this invention is a reentrant cavity type heat transfer tube, and the heat transfer tube in the 2nd path is offering the 2 way type evaporator for chiller systems which is a capacitor type heat transfer tube.
[0019] Still more nearly another purpose of this invention is [in / are the 2 way type evaporator which has the 1st path which operates by the filled-liquid method, and the 2nd path which operates by the falling film evaporator, and / both methods] offering the 2 way type evaporator which performs heat transfer with the optimal single tube type.

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MEANS

[Means for Solving the Problem] The purpose of these and other this inventions is attained by the steamy compression cooling system for cooling the liquid containing a compressor, a capacitor, an expander, and an evaporator. The compressor, the capacitor, the expander, and the evaporator form the closed loop of a refrigerant flow to link to a serial and for a refrigerant circulate. The evaporator of a system contains the external shell which has upper limit, a lower limit, a refrigerant inlet port, and an outlet, respectively. An evaporator contains further two or more almost level heat transfer tubes held in external shell. Some heat transfer tubes [at least] adjoin the upper limit of shell, and some tubes [at least] adjoin the lower limit of shell. shell. The tube is formed so that the liquid cooled may flow these tubes.
[0021] An evaporator receives the refrigerant which passes external shell via a refrigerant inlet port again, and includes a means to distribute a refrigerant to the heat transfer tube adjoined and arranged on the upper limit of external shell. The refrigerant flow closed loop of a cooling system is constituted so that it may be held at liquid level to which at least 25% of a level tube is flooded with a liquefied refrigerant at the time of operation in the condition that the cooling system was stabilized by the liquid level of the refrigerant in external shell. The level tube which is not dipped in a liquefied refrigerant operates in flowing-down liquid membrane transfer mode. Many do not consist of the total flow of the refrigerant with which the flow rate of the refrigerant which flows a distribution means flows from a refrigerant inlet port to a refrigerant outlet in the case of such stable operation.
[0022] In the desirable example, an evaporator is the thing of the type with which the liquid which should be cooled forms two paths via external shell. The 2nd path goes via the 2nd group of a level tube via the 1st group of the level heat transfer tube with which the 1st path adjoins the lower limit of shell.
[0023] Other purposes and advantages of this invention are made clear from the following detailed explanation using an attached drawing. In addition, in the attached drawing, the sign identically same to a considerable member is attached.
[0024]
[Embodiment of the Invention] Drawing 4 shows roughly the chiller 10 which incorporated the flowing-down liquid membrane / filled-liquid hybrid evaporator 50 concerning this invention. The closed loop of the refrigerant flow of the criterion which a refrigerant flows a capacitor 14, expansion equipment 16, and an evaporator 50 from a compressor 12, and returns to a compressor 12 after that is used for a chiller 10.
[0025] An evaporator 50 contains the external shell 52 which two or more level heat transfer tubes 54 which can be set to a bundle penetrate. When drawing 5 is furthermore referred to, in the illustrated example, an evaporator is an evaporator of the 2 way type type which has a water can 56 at the end and has the partition 58 divided into the inlet-port section 60 and the outlet section 62. The inlet-port section 60 opens an inlet port 64 and the outlet section 62 for free passage to an outlet 66, respectively. The water which flowed into the inlet-port section 60 via the inlet port 64 flows to the edge 70 of the opposite side via the 1st tube group 68 which adjoins the lower limit of the evaporation shell 50. the 2nd tube group 72 which water reverses a direction here and adjoins the upper limit of shell -- going -- the outlet section 62 of a water can 56 -- return and here -- an outlet -- it is discharged from a water can via a conduit 66. According to the request, more partitions are used as everyone knows, and shoes are separate, and it is also possible to obtain two or more paths of the water which passes along shell 52 by dividing a tube into the group connected mutually.
[0026] At the time of actuation, a refrigerant mainly flows into the external shell 52 of an evaporator 50 via the

refrigerant inlet port 74 in the state of a liquid, and mainly flows out of steamy shell via the refrigerant outlet 76 by the gaseous state.

[0027] it is shown in both drawing 4 and drawing 5 -- as -- an inlet port -- the refrigerant which flowed into the evaporator via the inlet port 74 through the conduit 78 passes along the distribution system 80 arranged so that it might lie on the best location of the 2nd group of a tube 72. A distribution system consists of a series of spray heads or nozzles 82. all the refrigerants with which a spray head or a nozzle passes along evaporator shell -- the topmost part of a tube -- suitable -- distribution -- or it is allotted on the best location of a tube so that it may be sprayed.

[0028] In an operational stability condition, by restoration of the refrigerant in a system 10, and the design by the whole closed loop of a refrigerant flow, the liquid level 51 of the liquefied refrigerant in the external shell 52 is set up so that at least 25% of the level heat transfer tube near the lower limit of shell (%) may be held in a location which is dipped in a liquefied refrigerant.

[0029] Consequently, in such an operational stability condition, while an evaporator 50 operates by the tube arranged on the lower part of the evaporator which operates by the filled-liquid heat transfer method, the tube which is not dipped in a liquefied refrigerant operates by the falling-film-evaporator heat transfer method.

[0030] It is very important to always fully soak all heat transfer tubes in a high performance evaporator, in order for the optimal heat transfer to carry out from all tubes. In order to attain this result, the flowing-down liquid membrane / filled-liquid evaporator by this invention operate, where 25 to 75% of level heat transfer tube is dipped in a liquefied refrigerant at the time of the actuation by which the cooling system was stabilized. In the desirable example, a system is designed so that about 50% of heat transfer tube may be dipped in a liquefied refrigerant in the condition that the cooling system was stabilized.

[0031] Although the hybrid type evaporator was shown and described about passage arrangement of the type which flows upwards from the bottom, this may be applied to passage arrangement of the type which flows from width to width. In such arrangement, the hot water which flowed flows one bundle side, and comparatively cold water flows another bundle side.

[0032] In the still more nearly another desirable example of this invention, an evaporator 50 is the thing of a type with which the liquid which should be cooled forms two paths via the external shell 52 and which was mentioned above. In this example, the tube group 68 of the 1st or a lower part is common knowledge as what is known as a reentrant cavity type heat transfer tube, and demonstrates high performance in a filled liquid system evaporator. As an example of a such reentrant cavity type tube, available turbo B1-3 are commercially mentioned from a WORUBERIN tube company (Wolverine Tube Company). In this example, since the 2nd or the upper tube group 72 is used for the application of a capacitor, he is the thing of the type generally designed, and he is a thing available "spike type capacitor tube" type especially commercially from WORUBERIN Tube Company as a turbo C1 or a heat transfer tube of C2.

[0033] By using the heat transfer tube of a type which is different in an upper part and lower part side, a high heat transfer coefficient can be attained with both the filled-liquid section of an evaporator, and a flowing-down liquid membrane section. However, a final target is optimizing heat transfer in both a flowing-down liquid membrane evaporator section and a filled-liquid evaporator section. Tubes do not need to differ. This target is implementation-ized by the single tube which can offer the optimal heat transfer by both methods.

[0034] The advantage of the arrangement explained above is useful especially when used with the 2 way type evaporator of the type which flows upwards from the bottom. In order to understand such an advantage completely, first, with the typical 2 way type evaporator, the temperature of the water which flows from an inlet port 64 is about 54 Fahrenheit, and he should understand that are cooled by 48 degrees from Fahrenheit 47 [about] at the termination 70 of the 1st path, and it is cooled further and it is cooled to about 44 Fahrenheit in case this water flows out of an evaporator at an outlet 66. Therefore, the temperature of the water which passes a tube is comparatively high in a lower part or a pool boiling section, and comparatively low in the upper part or a flowing-down liquid membrane heat transfer section.

[0035] The advantage of this example is explained as follows bearing this in mind. A pool boiling multiplier is proportional to square [of wall overheating (deltaTWS) (wall super-heat) defined as a difference between the temperature of the wall of a tube, and the saturation temperature of a refrigerant] mostly. On the contrary, flowing-down liquid membrane factor of evaporation is mostly in inverse proportion to the 4 roots of wall

overheating. Thus, at the 1st path of the evaporator which has the upper passage arrangement from the bottom, wall overheating is comparatively high and a nucleate-boiling multiplier becomes high. However, when it assumes that a filled liquid system evaporator and a heat transfer tube same type are in the 2nd tube, at the 2nd path where overheating of a wall becomes small as the fluid of a tubeside gets cold relatively, a nucleate-boiling multiplier has a possibility of decreasing also 3 to 4 times.

[0036] In a typical high efficiency chiller, the differences of the temperature of the water at the time of water going into a heat exchanger and the saturation temperature of a refrigerant are about 12 Fahrenheit, and the difference at the time of water coming out of a heat exchanger is the smallness of about 2 times from Fahrenheit 1. Therefore, if it goes into the 2nd path and a temperature gradient becomes small, the heat transfer coefficient of a falling film evaporator will become higher than a pool boiling multiplier. This is applied especially when the suitable heat transfer front face is used for both paths in this example.

[0037] He can understand that the heat exchanger by this invention operates without a refrigerant recirculation pump, can attain a high heat transfer coefficient in both pool boiling and a flowing-down liquid membrane evaporation method, and the advantage is acquired by this.

[0038] As mentioned above, if this invention is summarized, this invention is a steamy compression cooling system for specifically cooling a liquid about a chiller with a hybrid falling-film-evaporator evaporator, and it has the spray distributor for distributing a liquefied refrigerant to the whole tube in shell and a tube type evaporator. The differential pressure within the loop formation of the refrigerant flow which passes an evaporator is the single means which makes the flow which passes along a spray distributor. An evaporator operates as a hybrid falling-film-evaporator heat exchanger (i.e., a condition [half-filled-liquid]). A liquefied refrigerant is filled by the lower part part of evaporator shell in order to wet the tube in the direction of under a bundle. The tube of the upper one is wet only by the refrigerant spray from a spray distributor. A system operates in the condition of having been stabilized and, therefore, at least 25% of the tube in an evaporator operates by the filled-liquid heat transfer method. The fill of the refrigerant in a system can be decreased and it is not necessary to use a circulation system and a pump for coincidence by this system.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the schematic diagram of the conventional chiller system.
[Drawing 2] It is the partial schematic diagram of the conventional chiller system which has a filled liquid system evaporator.
[Drawing 3] It is the partial schematic diagram of the conventional chiller system which has a falling-film-evaporator evaporator.
[Drawing 4] It is the schematic diagram of the chiller system which has the flowing-down liquid membrane / filled-liquid hybrid evaporator by this invention.
[Drawing 5] It is the sectional view which the flowing-down liquid membrane / filled-liquid hybrid evaporator of the type shown in drawing 4 simplified.
[Description of Notations]
10 -- Chiller
12 -- Compressor
14 -- Capacitor
16 -- Expansion equipment
50 -- Flowing-down liquid membrane / filled-liquid hybrid evaporator
52 -- External shell
54 -- Level heat transfer tube
56 -- Water can
68 -- 1st tube group
74 -- Refrigerant inlet port
76 -- Refrigerant outlet
78 -- inlet port -- a conduit
80 -- Distribution system

[Translation done.]

* NOTICES *

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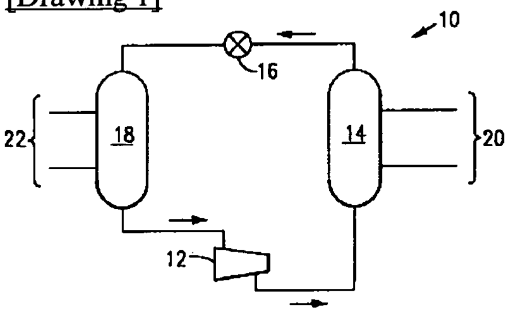
damages caused by the use of this translation.

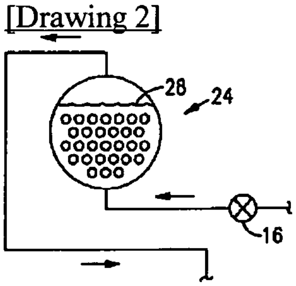
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

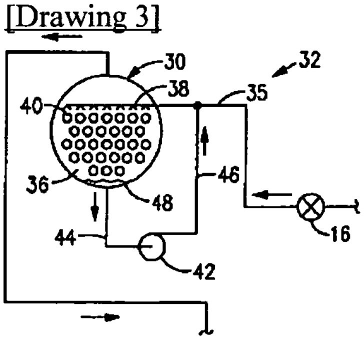
[Drawing 1]



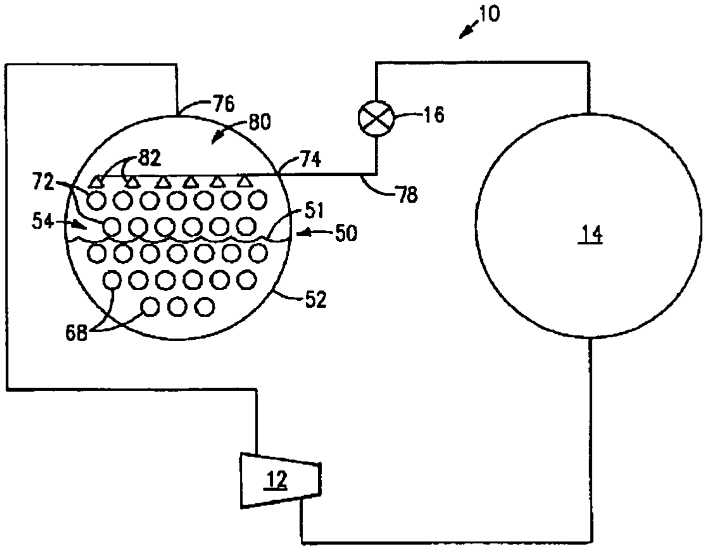
[Drawing 2]



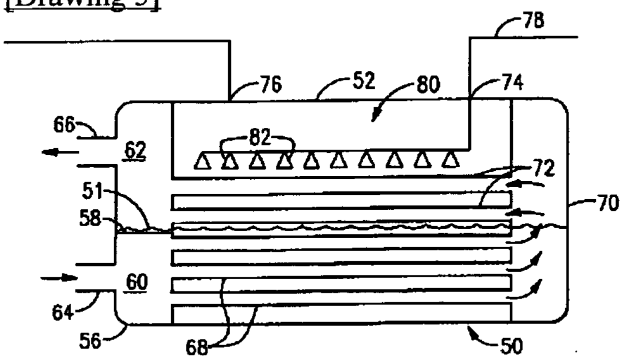
[Drawing 3]



[Drawing 4]



[Drawing 5]



[Translation done.]